

Horizon EUROPE - Specific Programme

proposal for a Decision of the Council [ST_8550/19_INIT]

Clusters /as described in Annex I, Pillar II, sections 1 – 6/

Cluster 1: 'Health'

BROAD LINES – 1. Health throughout the Life Course:

- Understanding the early development and the aging process throughout the life course;
- pre- and neo-natal, maternal, paternal, infant and child health as well as the role of parents, family and educators;
- Health needs of adolescents, including factors influencing mental health;
- Health consequences of disabilities and injuries;
- Research on measures to plan, implement and monitor rehabilitation throughout the life course and especially early individual rehabilitation programme (EIRP) for children affected by disabling pathologies
- Healthy ageing, independent and active life, including social participation for the elderly and/or disabled people;
- Health education and health literacy, including digital.

BROAD LINES – 2. Environmental and Social Health Determinants :

- Technologies and methodologies for assessing hazards, exposures and health impact of chemicals, indoor and outdoor pollutants and other stressors related to climate change, workplace, lifestyle or the environment and combined effects of several stressors;
- Environmental, occupational, socioeconomic, cultural, genetic and behavioural factors impacting physical and mental health and well-being of people and their interaction, with special attention to vulnerable and disadvantaged people, age-specific and gender-specific issues where relevant, and including the impact on health of the design of buildings, products and services;
- Risk assessment, management and communication, supported by transdisciplinary approaches, where relevant, and improved tools for evidence-based decision-making, including replacement of and alternatives to animal testing;
- Capacity and infrastructures to securely collect, share, use, re-use and combine data on all health determinants, including human exposure, and ensure their connection with databases on environmental parameters, lifestyles, health status and diseases, at EU and international level;
- Health promotion and primary prevention interventions, including occupational aspects.

BROAD LINES – 3. Non-Communicable and Rare Diseases

- Understanding the mechanisms underlying the development of non-communicable diseases, including Cardiovascular diseases;

- Longitudinal population studies to support understanding health and disease parameters and help stratifying populations in support of the development of preventive medicine;
- Diagnostic tools and techniques for earlier and more accurate diagnosis and for timely patient-adapted treatment, enabling delay and/or reversal of the progression of disease;
- Prevention and screening programmes, in line with or going beyond WHO, UN and EU recommendations;
- Integrated solutions for self-monitoring, health promotion, disease prevention, and management of chronic conditions and multi-morbidities, including neurodegenerative and cardiovascular diseases;
- Treatments, cures or other therapeutic interventions, including both pharmacological and nonpharmacological treatments;
- Palliative care;
- Areas of high unmet clinical need, such as rare diseases, including paediatric cancers
- Assessment of comparative effectiveness of interventions and solutions, including based on Real World Data (RWD);
- Implementation research to scale up health interventions and support their uptake in health policies and systems;
- Development of research and improvement of information, care and treatment, including personalised medicine, for rare diseases.

BROAD LINES – 4. Infectious Diseases, including poverty-related and neglected diseases

- Understanding infection-related mechanisms;
- Drivers for the emergence or re-emergence of infectious diseases and their spread, including transmission from animals to humans (zoonosis), or from other parts of the environment (water, soil, plants, food) to humans, as well as impact of climate change and ecosystems evolutions on the dynamics of infectious diseases;
- Prediction, early and rapid detection, control and surveillance of infectious diseases, healthcare-associated infections and environmental related factors;
- Combatting antimicrobial resistance, including epidemiology, prevention, diagnosis, as well as the development of new antimicrobials and vaccines;
- Vaccines, including vaccine platform technologies, diagnostics, treatments and cures for infectious diseases, including co-morbidities and co-infections
- Addressing low vaccine uptake, understanding vaccine hesitancy and building vaccine confidence;
- Effective health emergency preparedness, response and recovery measures and strategies, involving communities, and their coordination at regional, national and EU level;
- Barriers to the implementation and uptake of medical interventions in clinical practice as well as in the healthcare system;
- Trans-border aspects of infectious diseases and specific challenges in low- and middle-income countries (LMICs), such as AIDS, tuberculosis and tropical diseases, including malaria, also in relation to migratory flows and, in general, to increased human mobility.

BROAD LINES – 5. Tools, Technologies and Digital Solutions for Health and Care, including personalised medicine

- Tools and technologies for applications across the health spectrum and any relevant medical indication, including functional impairment;
- Integrated tools, technologies, medical devices, medical imaging, biotechnology, nanomedicine and advanced therapies (including cellular and gene therapy), and digital solutions for human health and care, including artificial intelligence, mobile solutions and telehealth, while addressing, when relevant, cost-efficiency production aspects at an early stage (in order to optimize the industrialisation stage and the potential of innovation to become an affordable medicinal product);
- Piloting, large-scale deployment, optimisation, and innovation procurement of health and care technologies and tools in real-life settings including clinical trials, implementation research including diagnostics based on personalised medicine;
- Innovative processes and services for the development, manufacturing and rapid delivery of tools and technologies for health and care;
- The safety, efficacy, cost-effectiveness, interoperability and quality of tools and technologies for health and care as well as their ethical, legal and social impact, including social acceptance issues;
- Regulatory science and standards for health and care technologies and tools;
- Health data management, including data interoperability, integration, analytical and visualisation methods, decision making processes, building on artificial intelligence, data mining, big data technologies, bioinformatics and high performance computing technologies to foster personalised medicine including prevention, and to optimise the health journey.

BROAD LINES – 6. Health Care Systems

- Supporting the knowledge base for reforms in health systems and policies in Europe and beyond;
- New models and approaches for health and care, including personalised medicine approaches, management and organisational aspects, and their transferability or adaptation from one country/region to another;
- Improving health technology assessment;
- Evolution of health inequality and effective policy response;
- Future health workforce and its needs, including digital skills;
- Improving timely, reliable, safe and trustworthy health information and use/reuse of health data, including electronic health records, with due attention to data protection, including the misuse of personal life style and health information, security, accessibility, interoperability, standards, comparability and integrity;
- Health systems resilience in absorbing the impact of crises and to accommodate disruptive innovation;
- Solutions for citizen and patient empowerment, self-monitoring, and interaction with health and social care professionals, for more integrated care and a user-centred approach, while considering equal access;
- Data, information, knowledge and best practice from health systems research at EU-level and globally building on existing knowledge and databases.

Cluster 2: 'Culture, Creativity and Inclusive Society'

BROAD LINES – 1. Democracy and Governance

- The history, evolution and efficacy of democracies, at different levels and in different forms; the role of education, cultural and youth policies as cornerstones of democratic citizenship;
- The role of social capital and access to culture in strengthening democratic dialogue and civic participation, open and trusting societies;
- Innovative and responsible approaches to support the transparency, accessibility, responsiveness, accountability, trustworthiness, resilience, effectiveness and legitimacy of democratic governance in full respect of fundamental and human rights and of the rule of law;
- Strategies to address populism, racism, polarisation, corruption, extremism, radicalisation, terrorism and to include, empower and engage citizens;
- Analysis and development of social, economic and political inclusion and inter-cultural dynamics in Europe and beyond;
- Better understand the role of journalistic standards and user-generated content in a hyper-connected society and develop tools to combat disinformation;
- The role of multi-cultural including spiritual identities, in relation to democracy, citizenship and political engagement, as well as EU founding values such as respect, tolerance, gender equality, cooperation and dialogue;
- Support research to understand identity and belonging across communities, regions and nations;
- The impact of technological and scientific advancements, including big data, online social networks and artificial intelligence on democracy, privacy and the freedom of speech;
- Deliberative, participatory and direct democracy and governance and active and inclusive citizenship, including the digital dimension;
- The impact of economic and social inequalities on political participation and democratic governance, and research on to what extent it can contribute of reversing inequalities and combatting all forms of discrimination including gender to a more resilient democracy;
- Human, social and political dimensions of criminality, dogmatism and radicalisation, in relation to those engaged or potentially engaged in such behaviour as well as to those affected or potentially affected;
- Combatting disinformation, fake news and hate speech, and their impact in shaping the public sphere;
- The EU as an international and regional actor in multilateral governance, including new approaches to science diplomacy;
- Efficiency of justice systems and improved access to justice based on judiciary independence and principles and human rights, with fair, efficient and transparent procedural methods both in civil and criminal matters.

BROAD LINES – 2. Cultural Heritage

- Heritage studies and sciences, with cutting edge technologies and innovative methodologies, including digital ones;

- Access to and sharing of cultural heritage, with innovative patterns and uses and participatory management models;
- Research for the accessibility of cultural heritage through new technologies, such as cloud services, including but not limited to a European cultural heritage collaborative space , as well as encouraging and facilitating transmission of know-how and skills. This will be preceded by an impact assessment;
- Sustainable business models to strengthen the financial foundation of the heritage sector;
- Connect cultural heritage with emerging creative sectors, including interactive media, and social innovation;
- The contribution of cultural heritage to sustainable development through conservation, safeguarding, developing, and regeneration of cultural landscapes, with the EU as a laboratory for heritage-based innovation and sustainable cultural tourism;
- Conservation, safeguarding, enhancement, restoration and sustainable management of cultural heritage and languages including the use of traditional skills and crafts or cutting edge technologies including digital;
- Influence of cultural memories, traditions, behavioural patterns, perceptions, beliefs, values, sense of belonging and identities. The role of culture and cultural heritage in multi-cultural societies and patterns of cultural inclusion and exclusion.

BROAD LINES – 3. Social and Economic Transformations

- Knowledge base for advice on investments and policies especially education and training, for high value added skills, productivity, social mobility, growth, social innovation and job creation. The role of education and training to tackle inequalities and underpin inclusion, including school-failure prevention;
- Social sustainability beyond GDP- only indicators especially new economic and business models and new financial technologies;
- Statistical and other economic tools for a better understanding of growth and innovation in a context of sluggish productivity gains and/or structural economic changes;
- New governance models in emerging economic areas and market institutions;
- New types of work, the role of work, upskilling, trends and changes in labour markets and income in contemporary societies, and their impacts on income distribution, work-life balance, working environments, non-discrimination including gender equality and social inclusion;
- Greater understanding of the societal changes in Europe and their impact;
- The effects of social, technological and economic transformations on access to safe, healthy, affordable and sustainable housing;
- Tax and benefits systems together with social security and social investment policies, with a view to reversing inequalities in a fair and sustainable way and addressing the impacts of technology, demographics and diversity;
- Inclusive and sustainable development and growth models for urban, semi-urban and rural environments;
- Understanding human mobility and its impacts in the context of social and economic transformations, considered in the global and local scales for better migration governance, respect of differences, long-term integration of migrants including refugees and impact of related policy

interventions; respect of international commitments and human rights and issues of development aid and cooperation; greater, improved access to quality education, training, labour market, culture, support services, active and inclusive citizenship especially for the vulnerable, including migrants;

- Tackling of major challenges concerning European models for social cohesion, immigration, integration, demographic change, ageing, disability, education, poverty and social exclusion;
- Advanced strategies and innovative methods for gender equality in all social, economic and cultural domains, and to deal with gender biases and gender-based violence;
- Education and training systems to foster and make the best use of the EU's digital transformation, also to manage the risks from global interconnectedness and technological innovations, especially emerging online risks, ethical concerns, socio-economic inequalities and radical changes in markets;
- Modernisation of public authorities governance and management systems to engage citizens and meet their expectation regarding service provision, transparency, accessibility, openness, accountability and user centricity.

Cluster 3: 'Civil Security for Society'

BROAD LINES – 1. Disaster-Resilient Societies

- Technologies, capabilities and governance for first responders for emergency operations in crisis, disaster and post-disaster situations and the initial phase of recovery;
- The capacities of society to better prevent, manage and reduce disaster risk, including through nature-based solutions, by enhancing forecasting capabilities, prevention, preparedness and response to existing and new risks and domino effects, impact assessment and a better understanding of the human factor in risk management and risk communication strategies;
- More effectively support the build-back-better philosophy of the Sendai Framework through better understanding of post-disaster recovery and research into more effective post-disaster risk assessment;
- Interoperability of equipment and procedures to facilitate cross-border operational cooperation and an integrated EU market.

BROAD LINES – 2. Protection and Security

- Innovative approaches and technologies for security practitioners (such as police forces, fire brigades, medical services, border and coast guards, customs offices), in particular in the context of, digital transformation and interoperability of security forces, operators of infrastructure, civil society organisations, and those managing open spaces;
- Analysis of cross-border crime phenomena, advanced methods of fast, reliable, standardised and privacy enhanced data sharing and collection as well as best practices;
- Human and socio-economic dimensions of criminality and violent radicalisation, in relation to those engaged or potentially engaged in such behaviour as well as to those affected or potentially affected, including understanding and tackling terrorist ideas and beliefs and crimes based on gender, sexual orientation or racial discrimination;
- Analysis of security aspects of new technologies such as DNA-sequencing, genome editing, nanomaterials and functional materials, Artificial Intelligence, autonomous systems, drones,

robotics, quantum computing, cryptocurrencies, 3D printing and wearables, blockchain, as well as improving awareness of citizens, public authorities and industry to prevent the creation of new security risks and to reduce existing risks, including from those new technologies;

- Improved foresight and analysis capabilities for policy making and at strategic level on security threats;
- Protection of critical infrastructures as well as open and public spaces from physical, digital and hybrid threats, including the effects of climate change;
- Monitoring and combatting disinformation and fake news with implications for security, including developing capabilities to detect the sources of manipulation;
- Technological development for civil applications with the scope to enhance, where appropriate, interoperability between civil protection and military forces;
- Interoperability of equipment and procedures to facilitate cross-border, intergovernmental and inter-agency operational cooperation, and develop an integrated EU market;
- Developing tools and methods for an effective and efficient Integrated Border Management, in particular to increase reaction capability and improved capacity to monitor movements across external borders to enhance risk detection, incident responding and crime prevention;
- Detection of fraudulent activities at border crossing points and throughout the supply chain, including identifying forged or otherwise manipulated documents and detecting trafficking in human beings and illicit goods;
- Ensuring the protection of personal data in law enforcement activities, in particular in view of rapid technological developments, including confidentiality and integrity of information and traceability and processing of all transactions;
- Developing techniques for identifying counterfeit products, for enhancing protection of original parts and goods and for controlling transported products.

BROAD LINES – 3. Cybersecurity

- Technologies across the digital value chain (from secure components and quantum-resistant cryptography to self-healing software and networks);
- Technologies, methods, standards and best practices to address cybersecurity threats, anticipating future needs, and sustaining a competitive European industry, including tools for electronic identification, threat detection, cyber hygiene, as well as training and education resources;
- An open collaboration for European cybersecurity competence network and competence centre.

Cluster 4: 'Digital, Industry and Space'

BROAD LINES – 1. Manufacturing Technologies

- Breakthrough manufacturing technologies such as biotechnological production, additive manufacturing, industrial, collaborative, flexible and intelligent robotics, human integrated manufacturing systems, also promoted via an EU network of industrially-oriented infrastructures, which provide services to accelerate technological transformation and uptake by EU industry;
- Breakthrough innovations using different enabling technologies across the value chain. Examples are converging technologies, artificial intelligence, digital twin, data analytics, control

technologies, sensor technologies, industrial, collaborative and intelligent robotics, human-centered systems, biotechnological production, advanced batteries and hydrogen, including renewable based hydrogen, and fuel cell technologies, advanced plasma and laser technologies;

- Skills, workspaces and businesses fully adapted to the new technologies, in line with European social values;
- Flexible, high-precision, zero-defect, low-pollution and -waste, sustainable and climate-neutral cognitive plants, in line with the circular economy approach, smart, and energy efficient manufacturing systems meeting customer needs;
- Breakthrough innovations in techniques for exploring construction sites, for full automation for on-site assembly and prefabricated components.

BROAD LINES – 2. Key Digital Technologies

- Micro- and nano-electronics, including design and processing concepts, components and manufacturing equipment responding to the specific requirements of digital transformation and global challenges, in terms of performance functionality, energy and material consumption and integration;
- Efficient and secure sensing and actuating technologies and their co-integration with computational units as the enabler of industry and the Internet of Things, including innovative solutions on flexible and conformable materials for human-friendly interacting objects;
- Technologies as complements or alternatives to nano-electronics, such as integrated quantum computing, transmission and sensing as well as neuromorphic computing components and spintronics;
- Computing architectures and accelerators, low-power processors for a wide range of applications including neuromorphic computing powering artificial intelligence applications, edge computing, digitisation of industry, big data and cloud computing, smart energy and connected and automated mobility;
- Computing hardware designs delivering strong guarantees of trusted execution, with built-in privacy and security protection measures for input/output data, quantum computing as well as processing instructions and adequate human machine interfaces;
- Photonics technologies enabling applications with breakthrough advances in functionality, integration and performance;
- System and control engineering technologies to support flexible, evolvable and fully autonomous systems for trustworthy applications interacting with the physical world and humans, including in industrial and safety critical domains;
- Software technologies enhancing software quality, cybersecurity and reliability with improved service life, increasing development productivity, and introducing built-in artificial intelligence and resilience in software and their architecture;
- Emerging technologies expanding digital technologies.

BROAD LINES – 3. Emerging Enabling Technologies

- support for future and emerging trends in key enabling technologies;
- support for emerging communities involving a human centered-approach from the outset;

- assessing the disruptive potential of new emerging industrial technologies, and their impact on people, industry, society and the environment, building interfaces with industrial roadmaps;
- broaden the industrial basis for adopting technologies and innovation with breakthrough potential, including development of human resources and in the global context.

BROAD LINES – 4. Advanced Materials

- Materials (including polymers, bio-, nano-, two-dimensional, smart and multi-materials (including lignocelluloses), composites, metals and alloys) and advanced materials (e.g. quantum, responsive, photonic and superconducting materials) designed with new properties and functionalisation and meeting regulatory requirements (while not leading to increased environmental pressures during their whole life-cycle, from production to use or end-of-life);
- Integrated materials processes and production following a customer-oriented and ethical approach, including pre-normative activities and life-cycle assessment, sourcing and management of raw materials, durability, reusability and recyclability, safety, risk assessment for human health and environment and risk management;
- Advanced materials enablers like characterisation (e.g. for quality assurance), modelling and simulation, piloting and upscaling;
- An EU innovation ecosystem of technology infrastructures¹⁴, networked and accessible to all relevant stakeholders, identified and prioritised in agreement with Member States, which provide services to accelerate technological transformation and uptake by EU industry, notably by SMEs; this will cover all key technologies necessary to enable innovations in the field of materials;
- Solutions based on advanced materials for cultural heritage, design, architecture and general creativity, with a strong user orientation, for adding value to industrial sectors and the creative industries.

BROAD LINES – 5. Artificial Intelligence and Robotics

- Enabling AI technologies such as explainable AI, ethical AI, human-controlled AI, unsupervised machine learning and data efficiency and advanced human-machine and machine-machine interactions;
- Safe, smart, collaborative and efficient robotics and complex embodied and autonomous systems;
- Human-centric AI technologies for AI-based solutions;
- Developing and networking the research competences in the area of AI across Europe under an open collaborative perspective while also developing the capacity for closed testing;
- The employment of AI and robotics to support people affected by disability, and inclusion of marginalised individuals;
- Technologies for open AI platforms including software algorithms, data repositories, agent-based systems, robotics and autonomous systems platforms.

BROAD LINES – 6. Next Generation Internet

- Technologies and systems for trusted and energy-efficient smart network and service infrastructures (connectivity beyond 5G, software defined infrastructures, Internet of things, systems of systems, cloud infrastructures, next generation optical networks, quantum, cognitive clouds and quantum internet, integration of Satellite Communications), enabling real-time

capabilities, virtualisation and decentralised management (ultrafast and flexible radio, edge computing, shared contexts and knowledge) to ensure scalable, efficient, reliable and trustworthy network performance suited for massive service deployment;

- Next Generation Internet applications and services for consumers, industry and society building on trust, fairness, interoperability, better user control of data, transparent language access, new multi modal interaction concepts, inclusive and highly personalised access to objects, information and content, including immersive and trustworthy media, social media and social networking as well as business models for transactions and services over shared infrastructures;
- Software-based middleware, including distributed ledger technologies such as blockchains, working in highly distributed environments, facilitating data mapping and data transfer across hybrid infrastructures with inherent data protection, embedding artificial intelligence, data analytics, security and control in Internet applications and services predicated on the free flow of data and knowledge;

BROAD LINES – 7. Advanced Computing and Big Data

- High Performance Computing (HPC): next generation of key exascale and post-exascale technologies and systems (e.g. low-power microprocessors, software, system integration); algorithms, codes and applications, and analytic tools and test-beds; industrial pilot test-beds and services; supporting research and innovation for and preferably participation by all the Member States a world-class HPC infrastructure, including the first hybrid HPC/Quantum computing infrastructures and for shared services in the EU;
- Big Data: Extreme-performance data analytics; "Privacy by design" in the analysis of personal and confidential Big Data; technologies for full-scale data platforms for re-use of industrial, personal and open data; data management, interoperability and linking tools; data applications for global challenges; methods for data science;
- Reduced carbon footprint of ICT processes, covering hardware, architecture, communication protocols, software, sensors, networks, storage and data centres, and including standardised assessments.

BROAD LINES – 8. Circular Industries

- Industrial symbiosis with resource flows between plants across sectors and urban communities; processes and materials, to transport, transform, re-use and store resources, combining the valorisation of by-products, waste, waste-water and CO₂;
- Valorisation and life-cycle assessment of materials and product streams with use of new alternative feedstocks, resource control, material tracking and sorting (including validated testing methods and tools for risk assessment for human health and environment);
- Eco-designed products, services and new business models for enhanced life-cycle performance, durability, upgradeability and ease of repair, dismantling, reuse and recycling;
- Effective recycling industry, maximising potential and safety of secondary materials and minimising pollution (non toxic material cycles), quality downgrading, and quantity dropouts after treatment;
- Elimination or, if no alternative, safe handling of substances of concern in the production and end-of-life phases; safe substitutes, and safe and cost-efficient production technologies;
- Sustainable supply and substitution of raw materials, including critical raw materials, covering the whole value chain.

BROAD LINES – 9. Low-Carbon and Clean Industries

- Process technologies, including heating and cooling, digital tools, automation and large-scale demonstrations for process performance and resource and energy efficiency; substantial reductions or avoidance of industrial emissions of greenhouse gases and pollutants, including particulate matter;
- CO2 valorisation from industry and other sectors;
- Conversion technologies for the sustainable utilization of carbon sources to increase resource efficiency and reduce emissions, including hybrid energy systems for the industry and energy sector with a decarbonisation potential;
- Electrification and use of unconventional energy sources within industrial plants, and energy and resource exchanges between industrial plants (for instance via industrial symbiosis);
- Industrial products that require low or zero carbon emissions production processes through the life cycle.

BROAD LINES – 10. Space, including Earth Observation

- European Global Navigation Satellite Systems (Galileo and EGNOS): innovative applications, global uptake including international partners, solutions improving robustness, authentication, integrity of services, development of fundamental elements such as chipsets, receivers and antennas, sustainability of supply chains, at cost-effective and affordable conditions, new technologies (e.g. quantum technologies, optical links, reprogrammable payloads), towards sustained exploitation of services for impact on societal challenges. Next generation systems development for new challenges such as security or autonomous driving;
- European Earth Observation system (Copernicus): leveraging the full, free and open data policy, develop innovative applications, European and global uptake, including non-space actors and international partnerships, research needed to maintain, improve and expand core services and research for space data assimilation and exploitation, robustness and evolution of services, sustainability of supply chains, sensors, systems and mission concepts (e.g. High Altitude Platforms, drones, light satellites); calibration and validation; sustained exploitation of services and impact on societal challenges; Earth observation data processing techniques, including big data, computing resources and algorithmic tools. Next generation systems development for challenges, such as climate change, polar and security; extension of the Copernicus product and service portfolio;
- Space Situational Awareness: developments to support robust EU capacity to monitor and forecast the state of the space environment e.g. space weather, including radiation hazards, space debris and near Earth objects. Developments of sensors technologies and new service concepts, such as space traffic management, applications and services to secure critical infrastructure in space and on Earth;
- Secure Satellite Communications for EU governmental actors: solutions supporting the EU's autonomy for governmental users including associated user equipment and architectural, technological and system solutions for space and ground infrastructure;
- Satellite Communications for citizens and businesses: integration of cost-effective, advanced satellite communications in the terrestrial networks to connect assets and people in underserved areas, as part of 5G-enabled ubiquitous connectivity, Internet of Things (IoT), and contributing to the Next Generation Internet (NGI) infrastructure. Enhancing the ground segment and user equipment, standardisation and interoperability, and preparation of quantum key communication by satellite to ensure EU industrial leadership;

- Non-dependence and sustainability of the supply chain: increased technology readiness levels in satellites and launchers; associated space and ground segments, and production and testing facilities in complementarity with ESA. To secure EU technological leadership and autonomy, improved supply chain sustainability at cost-effective and affordable conditions, reduced dependence on non-EU critical space technologies and improved knowledge of how space technologies can offer solutions to other industrial sectors and vice-versa;
- Space systems: in-orbit validation and demonstration services, including rideshare services for light satellites; space demonstrators in areas such as hybrid, smart or reconfigurable satellites, in-orbit servicing, manufacturing and assembly, energy supply using diversified sources; new industrial processes and production tools; ground systems; breakthrough innovations, and technology transfer, in areas such as recycling, green space, sustainable and peaceful use of space resources, artificial intelligence, robotics, digitisation, cost-efficiency, miniaturisation;
- Access to space: innovative technologies for increasing the technical compatibility and economic efficiency of European space launch systems, with regard to the launch of European Union satellites: low cost production processes, launcher reusability technologies and concepts for cost reduction; concepts for future launcher ground segments and adaptations of existing ground infrastructures (e.g. digitalisation, advanced data management); innovative space transportation services/concepts, including launch systems dedicated to light satellites (e.g. micro launchers), in complementarity with ESA.
- Space science: exploitation of scientific data delivered by scientific and exploration missions, combined with the development of innovative instruments in an international and interdisciplinary environment; contribution to precursor scientific missions for the evolution of the Space Programme.

Cluster 5: 'Climate, Energy and Mobility'

BROAD LINES – 1. Climate Science and Solutions

- Knowledge base on the current functioning and future evolution of the earth-climate and living system, as well as associated impacts, risks, and climate-responsible opportunities; effectiveness of different climate mitigation and adaptation solutions;
- Integrated climate neutral pathways, mitigation actions and policies covering all sectors of the economy, compatible with Earth system analyses, the Paris Agreement and the United Nations Sustainable Development Goals;
- Climate models, projections and techniques aiming to improve predictive capacity and climate services for businesses, public authorities and citizens, including cross-cutting aspects with air quality improvement;
- Adaptation pathways and support policies for vulnerable ecosystems, urban areas, critical economic sectors and infrastructure in the EU (local/regional/national), including improved risk assessment tools; water cycle and adaptation to climate change, such as flooding and water scarcity.

BROAD LINES – 2. Energy Supply

- Renewable energy and energy conservation technologies and solutions for power generation, heating and cooling, sustainable transport fuels and intermediate carriers, at various scales and development stages, adapted to geographic and socio-economic conditions and markets, both within the EU and worldwide;

- Disruptive renewable energy technologies for both existing and new applications and for breakthrough solutions including their environmental, economic and social impact;
- Technologies and solutions to reduce greenhouse gas emissions from fossil fuel-based as well as from bio- and waste-to-energy-based approaches producing power, heating, cooling or biofuels including via carbon capture, utilisation and storage (CCUS) and studies of socio-economic and ecological feasibility.

BROAD LINES – 3. Energy Systems and Grids

- Technologies and tools for networks to integrate renewables, storage solutions and new loads such as electro-mobility and heat pumps as well as the electrification of industrial processes;
- Multidisciplinary approaches to regionally dependent climate change related impact to energy security, including adaptation of existing technologies, as well as transition into the new energy supply paradigms;
- Pan-European energy network approaches to reliable energy supply, transmission and distribution;
- Integrated approaches to match renewable energy production and consumption at local level including on islands or remote regions, based on new services and community initiatives;
- Generation and network flexibility, interoperability and synergies between the different energy sources, networks, infrastructures and actors, also exploiting specific technologies;
- Technologies, services and solutions empowering consumer to be an active market player.

BROAD LINES – 4. Buildings and Industrial Facilities in Energy Transition

- Improve sector coupling : Processes, systems and business models supporting flexibility and efficiency of electricity and heat flows between an industrial plant or industrial clusters and the energy as well as transport system;
- Tools and infrastructure for process control of production plants to optimise energy flows and materials in interaction with the energy system;
- Relevant processes, design and materials, including low- and zero- emission industrial processes;
- Flexibility and efficiency of electricity, feedstock and heat in industrial plants and the energy system;
- Improved or new processes, design and materials to efficiently use, produce or store energy (including heat and cold) in sectors not covered by the “Digital, Industry and Space” cluster;
- Strategies and low emission technologies for revitalising coal- and carbon-intensive areas in transition;
- Smart buildings and large mobility hubs (ports, airports, logistic centres) as active elements of wider energy networks and of innovative mobility solutions;
- Buildings life-cycle design, construction, operation, including heating and cooling, and dismantling, taking into account circularity, energy and environmental performance, as well as indoor environmental quality, for energy and resource efficiency, for well-being and health impact on the inhabitants, climate resilience, carbon footprint and recycling; development and optimization of novel advanced materials to increase the energy, carbon and environmental performances of buildings over the life cycle;;

- New business models, approaches and services for renovation financing, enhancement of construction skills, engagement of buildings occupants and other market actors, addressing energy poverty and prenormative activities;
- Energy performance of buildings monitoring and control technologies for optimising energy consumption and production of building as well as their interaction with the overall energy system;
- Tools and smart appliances for energy efficiency gains in buildings;
- Renovation processes of existing buildings towards 'Nearly Zero Energy Buildings' and innovative technologies, including social aspects, e.g. citizen empowerment, and consumer awareness and engagement.

BROAD LINES – 5. Communities and Cities

- City/district energy/mobility systems towards the EU-wide deployment of carbon neutral, Positive Energy Districts and zero-emission mobility and logistics by 2050, boosting the global competitiveness of integrated EU solutions;
- Systemic urban planning, infrastructures systems and services including mutual interfaces and interoperability, standardisation, nature-based solutions and the use of digital technologies and space based services and data, taking into account the effects of projected climate change and integrate climate resilience and the influence on air and water quality;
- Quality of life for the citizens, safe, flexible, accessible and affordable energy and multi-modal mobility, urban social innovation and citizen engagement, cities' circular and regenerative capacity, urban metabolism and reduced environmental footprint and pollution;
- Global cities research agenda; mitigation, adaptation and resilience strategy development, spatial planning and other relevant planning processes.

BROAD LINES – 6. Industrial Competitiveness in Transport

- Merging of physical and digital vehicle/vessel/aircraft design, development and demonstration, manufacturing, operations, standardisation, certification and regulations and integration (including integration between digital design and digital manufacturing);
- Vehicle/vessel/aircraft concepts and designs, including their spare parts and software and technology updates, software solutions; using improved materials and structures, recycling/reusing materials; efficiency, energy storage and recovery, safety and security features considering users' needs, with less impact on climate, environment and health, including noise and air quality;
- On-board technologies and sub-systems, including automated functions, for all modes of transport taking account of relevant infrastructure interface needs and exploring; technological synergies between modes; multi-modal transport systems; safety/accidence avoidance systems and enhancing cybersecurity; leveraging progress in information technologies, and in artificial intelligence; developing the human-machine interface;
- New materials, techniques and methods of construction, operations and maintenance of infrastructures, ensuring reliable network availability, intermodal interfaces and multimodal interoperability, workforce safety, and full life-cycle approach;
- Addressing issues of merging physical and digital infrastructure design and development, infrastructure maintenance, regeneration and upgrading transport integration, interoperability and intermodality, resilience to extreme weather events, including adaptation to climate change.

BROAD LINES – 7. Clean, Safe and Accessible Transport and Mobility

- Electrification of all transport modes including new battery, fuel cell and hybrid technologies for vehicle/vessel/aircraft powertrains and auxiliary systems, fast charging/refuelling, energy harvesting and user-friendly and easily accessible interfaces with the charging/refuelling infrastructure, ensuring interoperability and seamless services provision; development and deployment of competitive, safe, high-performing and sustainable batteries for low and zero-emission vehicles considering all the conditions of using and during the different phases of its life cycle; development and deployment of competitive, safe, high-performing and sustainable batteries for low and zero-emission vehicles;
- Use of new and alternative sustainable fuels, including advanced bio-fuels and new, safe and smart vehicles/vessels/aircraft for existing and future mobility patterns and supporting infrastructure with reduced impact on the environment and public health; niche components and systems for environmentally friendly solutions (e.g. advanced data gathering systems, etc.) technologies and user-based solutions for interoperability and seamless services provision;
- Safe, accessible, inclusive and affordable mobility, reducing the harmful whilst enhancing the positive impact of mobility on social cohesion, the environment and human health, including shift to less polluting modes of transport and sharing schemes; Quality of life for the citizens, urban social innovation; the interest to reduce or to eliminate accidents and injuries in road transport.
- Climate resilient mobility systems, including infrastructures and logistics, to assure better connectivity for persons and goods, both on short and long haul distances;
- Systemic analysis of new mobility patterns and their impact on transport and citizens.

BROAD LINES – 8. Smart Mobility

- Digital network-and traffic management: advanced decision support systems; next generation traffic management (including multi-modal network and traffic management); contributing to seamless, multimodal and interconnected mobility for passengers and freight; use and limitations of big data; use of innovative satellite positioning/navigation (EGNOS/Galileo);
- Single European Sky: on-board and on-the-ground solutions for simultaneously higher degrees of automation, connectivity, safety, interoperability, performance, emission reduction and service;
- Rail technologies and operations for a high-capacity, silent, interoperable, and automated railway system;
- Smart shipping solutions for safer, more efficient waterborne operations;
- Large mobility hubs (e.g. railway stations, ports, airports, logistic centres) as active elements of innovative mobility solutions;
- Waterborne technologies and operations for safe and automated transport systems seizing the opportunities provided by waterborne transport;
- Connected, cooperative, interoperable and automated mobility systems and services, including technological solutions and non-technological issues, such as changes in user behaviour and mobility patterns.

BROAD LINES – 9. Energy Storage

- Technologies including liquid and gaseous renewable fuels and their associated value chains, as well as disruptive technologies, for daily to seasonal energy storage needs, including their impacts on the environment and climate;
- Smart, sustainable and durable batteries and the EU value chain, including the use of advanced material solutions, design, energy-efficient large-scale battery cell production technologies, reuse and recycling methods as well as efficient operation at low temperatures and standardisation needs;
- Hydrogen, in particular low carbon and renewable based hydrogen, including fuel cells, and the EU value chain from the design to end use across various applications.

Cluster 6: 'Food, Bioeconomy, Natural Resources, Agriculture and Environment'

BROAD LINES – 1. Environmental Observation

- User driven and systemic approaches including open data, to environmental data and information for complex modelling and predictive systems, business opportunities from exploitation and valorisation of existing and new data;
- Further development of products and services portfolio for environmental observations;
- Biodiversity status, ecosystem protection, climate change mitigation and adaptation, food security, agriculture and forestry, land use and land use change, urban and peri-urban development, natural resources management, sea and ocean resources management and conservation, maritime security, long term environmental trends, changes in seasonal variability, ambient air and atmospheric changes and other relevant domains;
- User oriented applications, to be delivered through the EuroGEOSS initiative, including their up scaling, to contribute to the preservation and management of European natural resources (including exploration of raw materials) and ecosystems services and their related value chain;
- Implementation of the Global Earth Observation System of Systems of the GEO (Group on Earth Observations) initiative.

BROAD LINES – 2. Biodiversity and Natural Resources

- The state and value of biodiversity, terrestrial, freshwater and marine ecosystems, natural capital and ecosystem services, including agro-ecosystems and the microbiome;
- Holistic and systemic approaches within a socio-ecological framework for the links between biodiversity, ecosystems and ecosystems services and their causality relationships with drivers of change, across different scales and economic activities, including the socio economic aspects and governance of transition processes to sustainability; y
- Modelling of trends and integrated scenarios for biodiversity, ecosystem services and good quality of life at different scales and horizons; the potential contribution of biotopes and ecosystems as carbon sinks under various climate change scenarios; potential conflicts of interests in utilization of natural resources and services;
- Ecotoxicology of compounds and new pollutants, their interactions, including combination effects, and environmental behaviour, and altered biochemical loops under changing climate, restoration of degraded areas;

- Mainstreaming biodiversity and ecosystem services in decision-making frameworks and accounting systems of governments and businesses, as well as quantification of ecological, economic and societal benefits;
- Adaptable and multi-functional nature-based solutions, addressing challenges in urban and peri-urban areas, rural and coastal and mountain areas related to climate change, natural disasters, biodiversity loss, ecosystem degradation, pollution, social cohesion and citizens' health and well-being;
- Multi-actor living labs approaches engaging authorities, stakeholders, business and civil society in co-designing and co-creating systemic solutions for the preservation, restoration and sustainable use of natural capital, and the governance of the transition to sustainability and sustainable management options in economic activities throughout whole value loops in different environmental, economic and social conditions.

BROAD LINES – 3. Agriculture, Forestry and Rural Areas

- Methods, technologies and tools for sustainable, resilient and productive agriculture and forestry, including adaptation to climate change;
- Sustainable management and efficient use of natural resources (e.g. soils, water, nutrients and biodiversity including genetic resources) in agriculture and forestry; alternatives to non-renewable resources and adoption of circular economy principles, including through the reuse and recycling of waste and by-products;
- Climate and environmental impact of activities in the primary sector; potential of agriculture and forestry as carbon sinks and for mitigation of greenhouse gas emissions including negative emission approaches; increasing adaptability of primary production to climate change;
- Integrated approaches to tackling plant pests and diseases; control of contagious and zoonotic animal diseases and animal welfare; prevention strategies, control and diagnostic and alternatives to the use of contentious pesticides, antibiotics and other substances also to tackle resistance;
- Antimicrobial resistance and threats from biological and agrochemical hazards, including pesticides, as well as chemical contaminants tackling the links between plant, animal, ecosystems and public health from One-Health and Global-Health perspectives;
- The use and delivery of ecosystem services in agriculture and forestry systems applying ecological approaches and testing nature-based solutions from farm to landscape levels for an environmentally friendly agriculture; support to organic farming;
- Agricultural and forestry systems from farm to landscape levels; the use and delivery of ecosystem services in primary production, e.g. through agro-ecology or through enhancing the role of forests in the prevention of floods and soil erosion;
- Innovations in farming at the interfaces between agriculture, aquaculture, forestry and in urban and peri-urban areas;
- New methods, technologies and tools for sustainable forest management and sustainable use of forest biomass;
- Support to EU plant protein production for food, feed and environmental services;
- Sustainable land use, rural development and territorial linkages; capitalising on the social, cultural, economic and environmental assets of rural areas for new services, business models, value chains and public goods;

- Digital innovations in farming, forestry and across value chains and rural areas through the use of data and development of infrastructures, technologies (such as AI, robotics, precision farming and remote sensing) and governance models;
- Agricultural and forestry knowledge and innovation systems and their interconnection at various scales; advice, building skills, participatory approaches and information sharing;
- Fostering international partnerships for sustainable agriculture for food and nutrition security.

BROAD LINES – 4. Seas, Oceans and Inland Waters

- Sustainable fisheries and aquaculture in all forms, including alternative sources of protein with increased food security, food sovereignty and climate resilience; monitoring and management tools;
- Strengthened resilience of marine and inland water ecosystems, including coral reefs thereby ensuring seas, ocean and river health, combating and mitigating the effects of natural and anthropic pressures like contaminants and marine litter (including plastics), eutrophication, invasive species, physical damage to the sea floor, overexploitation, including overfishing, underwater noise, acidification, seas, oceans and rivers warming, sea level rise, considering the intersection between land and sea, the cumulative impact of these issues and fostering a circular approach and a better understanding of ocean-human interactions;
- Governance at global and regional levels to ensure conservation and sustainable use of the resources of seas, oceans and inland waters;
- Technologies for the digital ocean (seafloor, water column and water surface) connecting services and communities in land-based, atmosphere, climate, space and weather related activities, and promoted through the Blue Cloud as part of the European Open Science Cloud;
- Monitoring, risk-based assessment and predictive/forecasting capacities including sea-level rise and other natural hazards e.g. storms surges, tsunamis as well as cumulative impact of human activities;
- Improve understanding of the hydrological cycle and regimes, hydromorphology at different scales and develop monitoring and predictive capacities for water availability and demand, floods and droughts, pollution and other pressures on water resources and aquatic environment. Exploit digital technologies to improve water resource monitoring and management; y
- Develop innovative solutions including societal governance, economic instruments and financing models, for smart water allocation addressing conflicts in water use, including exploiting the value in water, control of water pollutants, including plastics and microplastics and other emerging pollutants preferably at source, tackling other pressures on water resources, as well as water reuse, and protection and restoration of water ecosystems to good ecological status;
- Sustainable blue value-chains, including the sustainable use of fresh water resources, the multiple-use of marine space and growth of the renewable energy sector from seas and oceans, including sustainable use of micro- and macro- algae;
- Integrated approaches to sustainable management of inland and coastal waters which will contribute to environmental protection and adaptation to climate change;
- Nature-based solutions derived from marine, coastal and inland water ecosystem dynamics, biodiversity and multiple ecosystem services, which will enable systemic approaches to sustainably use the resources of seas, in particular of semi-closed European seas, and oceans and of inland waters, contribute to environmental protection and restoration, coastal management, and adaptation to climate change;

- Blue innovation including in the blue and digital economies, across coastline areas, coastal cities and ports in order to strengthen resilience of coastal areas and increase citizens' benefits;
- Better understanding of the role of seas and oceans in climate change mitigation and adaptation.

BROAD LINES – 5. Food Systems

- Evidence-based sustainable and healthy diets for people's well-being across their lifespan, including dietary patterns, improved nutritional quality of food and advances in understanding the impact of nutrition on health and well-being;
- Personalised nutrition especially for vulnerable groups, to mitigate the risk factors for diet-related and non-communicable diseases;
- Consumers' behaviour, lifestyle and motivations, including social and cultural aspects of food, promoting social innovation and societal engagement for better health and environmental sustainability throughout the entire food value chain, including retail patterns;
- Modern food safety and authenticity systems, including traceability, improving food quality and enhancing consumer confidence in the food system;
- Food system mitigation of and adaptation to climate change, including the exploration of the potential and use of the microbiome, of food crop diversity, and of alternative to animal proteins;
- Environmentally sustainable, circular, resource efficient and resilient food systems, from land and sea, towards safe drinking water and maritime issues, zero food waste throughout the entire food system, through reuse of food and biomass, recycling of food waste, new food packaging, demand for tailored and local food;
- Novel approaches, including digital tools and food systems for place-based innovation and empowerment of communities, fostering fair trade and pricing along the value chain, inclusiveness and sustainability through partnerships between industry (including SMEs and smallholders), local authorities, researchers and society.

BROAD LINES – 6. Bio-based Innovation Systems in the EU Bioeconomy

- Sustainable biomass sourcing, logistics and production systems, focusing on high-value applications and uses, social and environmental sustainability, impact on climate and biodiversity, circularity and overall resource efficiency, including water;
- Life sciences and their convergence with digital technologies for understanding, prospecting and sustainably using biological resources;
- Bio-based value chains, bio-based materials, including bio-inspired materials, chemicals, products, services and processes with novel qualities, functionalities and improved sustainability (including reducing emissions of greenhouse gases), fostering the development of (small and large scale) advanced biorefineries using a wider range of biomass; replacing current production of unsustainable products by outperforming biobased solutions for innovative market applications;
- Biotechnology, including cross sectoral cutting-edge biotechnology, for application in competitive, sustainable and novel industrial processes, environmental services and consumer products (Health biotechnology applications will be addressed by the Health cluster under this pillar);

- Circularity of the bio-based sector within the bioeconomy through technological, systemic, social and business model innovation to radically increase the value generated per unit of biological resource, keeping the value of such resources in the economy for longer, preserving and enhancing natural capital, designing out waste and pollution, supporting the principle of the cascading use of sustainable biomass through research and innovation and taking into account the waste hierarchy;
- Inclusive bioeconomy patterns with different actors participating in the creation of value, maximising societal impact and public engagement;
- Increased understanding of the boundaries, metrics and indicators of the bioeconomy and its synergies and trade-offs with a healthy environment, and trade-offs between food and other applications

BROAD LINES – 7. Circular Systems

- Systemic transition to a resource-efficient, bio-based and circular economy, with new paradigms in consumer interaction, new business models for resource efficiency and environmental performance; products and services stimulating resource efficiency and elimination or substitution of hazardous substances during the whole lifecycle; systems for sharing, reuse, repair, remanufacturing, recycling and composting; economic, social, behavioural, regulatory and financial conditions and incentives for such transitions;
- Metrics and indicators, based on a systemic approach, for measuring the circular economy and life cycle performance and enhancing social responsibility; governance systems which accelerate expansion of the circular economy, the bioeconomy and resource efficiency while creating markets for secondary materials; multi-stakeholder and cross-value chain collaboration; instruments for investment in the circular economy and bioeconomy;
- Solutions for sustainable and regenerative development of cities, peri-urban areas and regions, integrating the circular economy transformation with nature-based solutions, technological, digital, social, cultural and territorial governance innovations;
- Eco-innovation for prevention and remediation of environmental pollution from and exposure to hazardous substances and chemicals of emerging concern; looking also at the interface between chemicals, products and waste, and at sustainable solutions for primary and secondary raw materials production;
- Circular use of water resources, including reduction of water demand, prevention of losses, water reuse, recycling and valorisation of wastewater. Innovative solutions for the challenges for the water-food-energy nexus addressing impacts of agricultural and energy water use and enabling synergistic solutions.
- Sustainable subsurface management integrating geo-resources (energy, water, raw materials) and environmental conditions (natural hazards, anthropogenic impacts) across all relevant clusters, streamlining the positive contribution to a circular economy through pan-European geological knowledge and contributing towards an orchestrated science-based response to the Paris Agreement and to several UN Sustainable Development Goals.
- Develop and improve solutions and infrastructures for facilitating access to drinking, irrigation and sanitation water, involving inter alia desalination, in order to enable more efficient, energy and CO₂ friendly, as well as, circular use of water.